VI.B.2 Chemical Hydride Slurry for Hydrogen Production and Storage

Andrew W. McClaine (Primary Contact), Sigmar Tullmann, Kenneth Brown
Safe Hydrogen, LLC
30 York Street
Lexington, MA 02420-2009
Phone: (781) 861-7016; Fax: (781) 942-7413; E-mail: Andrew.McClaine@SafeHydrogen.com

DOE Technology Development Manager: Grace Ordaz
Phone: (202) 586-8350; Fax: (202) 586-9811; E-mail: Grace.Ordaz@ee.doe.gov

DOE Project Officer: Jesse Adams
Phone: (303) 275-4954; Fax: (303) 275-4753; E-mail: Jesse.Adams@go.doe.gov

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Subcontractors:
Hatch Technology LLC, Fall River, MA
Boston University, Boston, MA
Metallurgical Viability, Inc., Newark, DE
HERA Hydrogen Storage Systems, Longueuil, Quebec, Canada

Start Date: Contract start - 1 Jan 2004, Technical work start - 1 April 2004
Projected End Date: 31 December 2006

Objectives

Demonstrate that magnesium hydride slurry can meet the cost, safety, and energy density targets for on-board hydrogen storage of hydrogen fuel cell vehicles.

- Develop a stable and pumpable magnesium hydride slurry with energy density of 3.9kWh/kg and 4.8kWh/L
- Develop a compact robust mixing system to produce hydrogen from the slurry and to meet the 2kWh/kg and 1.5kWh/L system targets
- Define and assess the capital and operating costs of the recycling system required to make new magnesium hydride slurry from the materials remaining after the hydrolysis of magnesium hydride slurry and water
  - Separate and recycle the organic compounds from the hydroxide byproduct
  - Reduce the magnesium hydroxide to magnesium
  - Prepare magnesium hydride from magnesium and hydrogen
  - Prepare magnesium hydride slurry from the magnesium hydride and recycled organics.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Storage section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- A. Cost
- B. Weight and Volume
- C. Efficiency

- D. Durability
- G. System Life Cycle Assessments
- R. Regeneration Processes
- S. Byproduct/Spent Material Removal
- T. Heat Removal

Technical Targets

The evaluation of magnesium hydride slurry as a chemical hydride slurry for hydrogen storage, transportation, and production addresses many of the DOE technical targets. Tasks are devoted to the development of a pumpable, high energy density slurry, and to the development of a compact, robust system for hydrogen release and to the evaluation of the cost and efficiency of the process. It is anticipated that the system will exceed the 2010 targets and approach the 2015 targets for fuel cost, storage system cost, specific energy, and energy density. Information will also be produced to evaluate the targets for fill time, hydrogen quality, permeation and leakage, toxicity, and safety.

Approach

- Develop MgH_2 slurry
- Develop slurry/water mixing system for release of hydrogen
- Define organic recycle process
- Define MgH_2 production process
- Perform conceptual designs and economic analyses of four potential $Mg(OH)_2$ reduction processes: $MgCl_2$ electrolytic process, Solid-oxide Oxygen-ion-conducting Membrane (SOM) process, improved Hansgirg carbothermic process, and one promising new Mg reduction process
- Perform experimental investigation of the SOM process to provide additional data for the evaluation of a large-scale economic analysis of the SOM process
- Perform experimental investigation of carbothermic process to provide additional data for a large-scale economic analysis of a carbothermic process
- Reevaluate recycling process costs and recommend future cost reduction opportunities

Accomplishments

- Over 40 slurry compositions, varying MgH_2 fraction, mineral oil viscosity, dispersant selection, and particle size have been tested. Several of these compositions are acceptable. Demonstrated hydrogen storage is up to 9.6 wt.%. Further improvements are anticipated.
- More than 30 reaction tests have been performed. Reaction rates are rapid enough for mixer application. Reaction tests have produced 100% of the hydrogen theoretically possible participated in the reactions. The apparatus used for these measurements is shown in Figures 1 and 2. A continuous mixer design is currently under test. Continuous hydrogen release without external heat release has been achieved.

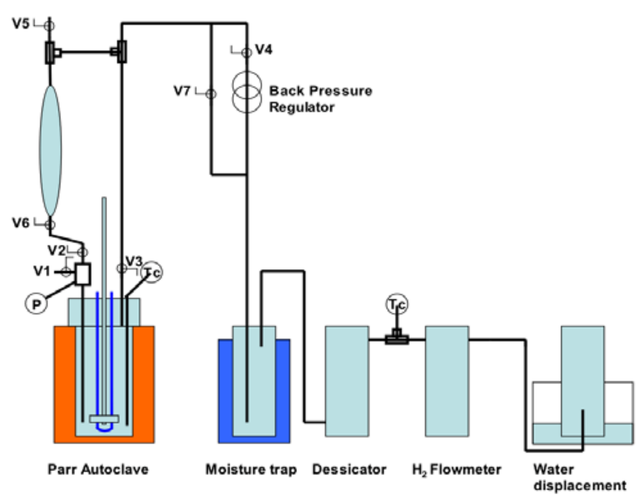

Figure 1. Schematic Drawing of Reaction Test Apparatus

- Studies of the most energy intensive part of the recycle system, the reduction of $Mg(OH)_2$ to Mg, are nearing completion. The SOM process is expected to offer the lowest energy consumption of less than 10kWh/kg of Mg. Capital costs and operating costs of the carbothermic reduction process are expected to be considerably less than those of the $MgCl_2$ reduction process.
- Magnesium hydride has been produced by reacting magnesium powder and hydrogen in a relatively simple process. Tests confirmed that the reaction was complete.
- Research on the SOM process has demonstrated a significant temperature reduction from 1300°C to 1150°C. Pure magnesium production was confirmed. The zirconia membrane was virtually unaffected after a 20 hour test (See Figures 3, 4, and 5). Operating life of the zirconia membrane is significantly increased by lower operating temperatures. The operating life of the membrane is expected to dominate the overall cost of the process.
- Preliminary life cycle analyses indicate that the magnesium hydride slurry approach for storing, transporting, and producing hydrogen can compete with liquefied and compressed hydrogen approaches on a total energy use basis assuming that electricity is produced by renewable sources, such as hydropower, wind, or solar, that produce electricity directly.

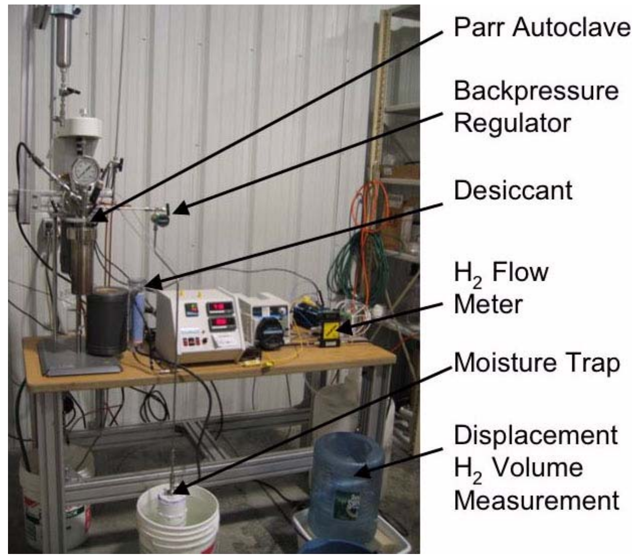

Figure 2. Photograph of Reaction Test Apparatus

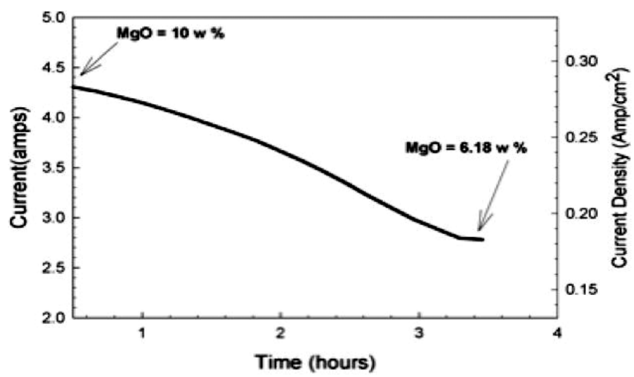

Figure 3. SOM Cell Electric Current During Reduction Test

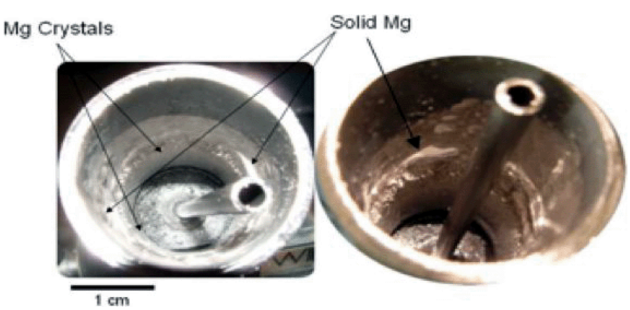

Figure 4. Photograph of Magnesium Crystals and Solid Magnesium Deposits in SOM Condenser

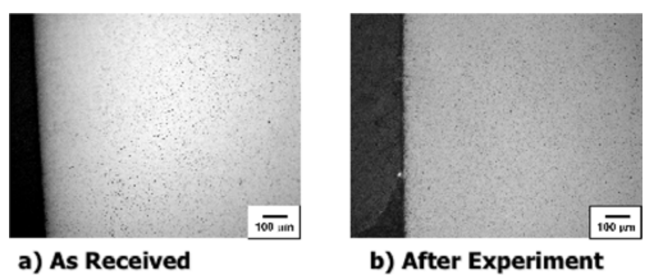

Figure 5. Photographs of Zirconia Membranes New and After 20 Hour Test at 1150°C